REVIEW ABSTRACT

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U.S. Department of Energy Directions in Photovoltaic Power Conditioner Development Using Smart Power/Power Integrated Circuit Technologies

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The power conditioning subsystem (PCS) is a dc-ac power inverter that includes conversion and control functions, the do- and at-side controls, and the protection functions, The dynamic interplay between the external requirements and internal requirements of a utility-interactive photovoltaic (W) system put the PCS in a critical path. it must be reliable, efficient and cost effective so that W power is competitive with conventional utility power in terms of economics and quality of power.

Unfortunately, PV PCS designs do not currently meet DOE cost and performance goals, However, there have been new advances in semiconductor technologies and possibilities for higher volume production of modular components for PCS hardware are on the horizon. In addition, smart power and power integrated circuit (PIC) technology has the potential to provide further improvements in cost, reliability and performance of new designs. The smart power concept refers to the integration of power switches, control functions, protection and sensing functions into one package. Smart power is the future research and development component of the balance-of-the-system program of DOE.

The basic thrust of this paper is on DOE sponsored current activities in PCS designs for PV applications using smart power or PIC technologies. These DOE directions and other on-going activities are all focused on meeting DOE cost, reliability and performance goals in order to accelerate the usage of PV systems on large scale. Specifically, the paper is divided into the following five subject areas

1. Current state-of-the-art of PCS designs suitable for low to medium power PV applications,
2. What Smart Power and PIC technology is, what technological barriers are and how they maybe overcome so that these devices will be suitable for PCS designs for photovoltaic applications,
3. How smart power and PiCs will improve cost, reliability and performance of PCSs.
4. What synergism exists in other applications that will be helpful in required PCS designs, meeting DOE cost and performance goals.
5. What the current DOE directions are that will be helpfuln realizing DOE cost and performance goals.

The paper analyzes these technical issues in detail and presents current and future research and development efforts in PV PCS development, A synopsis is provided below:

Smaller (50-250W) PV module PCSS that operate as an integral part of available PV modules and provide an output of 110 V at 60 HZ of utility quality power are currently being developed, Commercialization of this development could revolutionize the PV industry. Larger modular sized (50-250 kW) are also needed for PV operation in conjuction with batteries, diesel generators, and fuel cells for applications such as rural stand-alone plants and village power applications, The use of state-of-the-art technology such as ASICs, PLAs, and microprocessors is encouraged to promote modular designs that can use advanced automated manufacturing processes, The DOE leadership and funding are directed to achieve PCS performance, cost and reliability goals by utilizing potentials of smart power, PICs and above mentioned technologies. Dramatically reduced number of parts and interconnections will increase reliability and economy of scale while enhancing large volume production and reduced cost.

As part of the National Photovoltaic Program Balance-of-System Initiative, DOE, through SNL's PV Systems Research Department is funding another effort to determine the status of smart power and PIC technologies. A smart power workshop was also considered an important part of this effort. As a result, the first workshop on smart power was held at the California institute of Technology (Caltech) on May 20, 1987. Many presentations were made to cover both technology and applications. The workshop concluded that no real technical barrier existed that would prevent the application of smart power concepts to PV-specific systems. The preliminary feedback indicated that PCS manufacturers were interested in using this technology in their products.

The second workshop was held on December 8-9, 1993, at Caltech. Sponsors included DOE-W, SNL, National Renewable Energy Laboratory (NREL), interagency Advanced Power Group (IAPG), EPRI, Power Electronics Applications Center (PEAC), JPL, and Caltech. The results of this workshop were fourfold, First, the workshop provided an understanding of the current state-of-the-art of smart power and PIC technology. Second, the strengths and technological barriers of PIC technology were examined. Third, usage of PIC technology in various PV applications was identified. Fourth, programmatic steps to further the usage of the smart power technology were identified. The paper presents the PIC and smart prover technology barriers and the steps to overcome these barriers.

/mother source of current DOE funding opportunities includes the Small Business Innovation Research (SBIR) program. Modular power processing hardware for W operation is an objective of this effort. There is a need for modular and manufacturable PCS hardware that is a multipurpose electronic converter with code-accepted solid-state ac and do interfaces and control circuits. The paper presents all current programmatic efforts and sources of funding.

Presently, smart power technology finds applications in computers, electrical appliances, instrumentation, brushless DC motors, stepper motors, automatic test equipment, avionics, printers, security systems, automobiles and telecommunications, Terrestrial, space, military and aircraft power systems will find increasing use of this technology as it matures and its voltage and current ratings increase. This expanding market could quickly include PV systems, battery chargers, AC motor drives, and PCSs. The paper discusses this synergism and explains how DOE efforts will provide impetus in utilizing this synergism to accelerate PV power usage on a large scale.

The applications of smart power technology in the PCS hardware would provide more cost effective utility-interactive PV systems and expand the PV utlity-interactive market, world-wide. A PCS design using smart power technology will produce an integrated, nearly monolithic, PCS hardware that will further the concept of an "ac PV module." The ac PV module idea is being supported by funding from the Environmental Protection Agency (EPA), SBIR and SNL. The ac PV module concept was discussed within the DOE PV program as early as 1975, but necessary electronics were not available at the time. The paper elaborates on this concept.